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DEVELOPMENT OF A FULL-SCALE GROUND WAVE RADAR FOR OVER THE HORIZON REMOTE SENSING

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ABSTRACT

Ten years of ground wave research by the Centre for Cold Ocean Resources Engineering (C-CORE) and the Faculty of Engineering and Applied Science, Memorial University of Newfoundland has demonstrated the feasibility of using ground wave techniques for long range remote sensing. A Newfoundland company, Northern Radar Systems Limited has been formed as a joint undertaking of private industry and Memorial University to transfer this research to a full scale over-the-horizon radar at Cape Race, Newfoundland. With surveillance capability over a 120° sector out to a range of 400km, this radar will provide coverage over most of the Grand Banks including the Hibernia and Terra Nova oil fields.

Introduction

An increasing demand for the ability to detect surface and low altitude targets beyond the range of conventional microwave radar has given rise to a new generation of over-the-horizon (OTH) radars. These radars may use either forward or backscatter and will generally sense beyond the horizon by means of ionospheric reflection or groundwave propagation.

OTH radars that make use of the ionosphere to reflect energy into distinct sectors have the advantage of extremely long range detection capability but are "blind" in the near ranges. They also require complex sensing and analysis techniques to deal with the inconsistencies of the ionosphere. Ground wave radars (GWR) use groundwave propagation characteristics to detect beyond the horizon. They can track targets that are quite close while simultaneously detecting those out to some maximum range. Apart from the propagation path, maximum range is largely a function of processing and transmit power.

Technical Description

NRSL's prototype GWR is designed to cover a 120° sector out to a maximum range of 400km. Range resolution is 400m while azimuthal resolution is approximately 3.5° (this may be improved with beam splitting techniques). Transmit power is 10KW peak and the transmitted waveform is a modified frequency modulated continuous wave (FMCW). The radar prototype is sufficiently flexible to support many modes of operation and with adjustments to the receive array can operate from 5 MHz to 30 MHz.

The radar transmits a carrier in the HF band that is repeatedly swept over 375 kHz. The transmitter is a combination of four 2500 watt MOSFET power amplifiers. Although peak power limited a solid state amplifier was chosen for a number of reasons. Among these are its purity in the near-carrier spectrum and flexibility in that it can readily be used to drive multiple transmit

antennas giving a steerable transmit beam. The present transmit antenna is a single log periodic array that floodlights the entire 120° sector and provides 11dBi gain. The receive antenna is a forty element phased array and uses a combination of hardware and software beamforming. This gives a nominal beamwidth of 3.5 degrees that can be steered over the 120° sector. Coverage is limited to 120 degrees to eliminate grating lobe effects. The actual receive beamwidth varies from 2.5 degrees down the boresight to 5.0 degrees at 60 degrees from broadside.

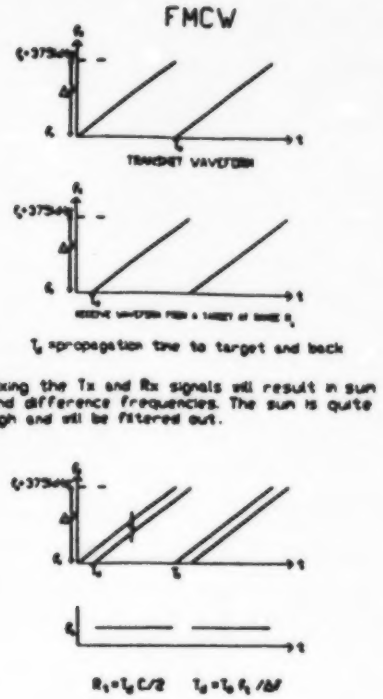
FMCW
TRANSMIT WAVEFORM
τ_d propagation time to target and back
Mixing the Tx and Rx signals will result in sum and difference frequencies. The sum is quite high and will be filtered out.

Fig. 1

By operating fmcw the NRSL radar has overcome the short duty cycle limitation of pulse radar. A range of 400km with 400m resolution in a conventional pulse radar would dictate a maximum duty cycle of 0.1%. For 1KW average power the radar would have to transmit 1000KW peak! In NRSL's system the exciter output, in addition to going to the transmitter, is frequency converted up by an amount equal to the first intermediate frequency and supplied to the receivers as the first local oscillator. As shown in figure 1, this removes the swept component of a signal reflected from a target and the receiver's output frequency is directly correlated to the targets range. Hence, range resolution becomes a function of the ability to resolve frequency as opposed to time.

Because the radar is monostatic (receiver and transmitter in the same area) it cannot be operated CW at very high transmit levels due to overloading of the receiver inputs. Receivers and transmitter are therefore gated on and off in a T/R fashion yielding a mode of operation dubbed fmicw (frequency modulated interrupted continuous wave). Still, the instantaneous range of the received signal levels is quite large and demand that the receivers have a spurious free dynamic range well in excess of 100dB. The NRSL receivers are triple conversion superheterodyne models supplied by Steinbrecher Corporation of Massachusetts who maintain this dynamic range right through the A/D to the digital output. The radars front-end hardware also includes gating control, step attenuation, oscillator synchronization and temporal gain.

A channel interface unit performs one fast Fourier transform on each receiver output per frequency sweep. This data is multiplexed into a CSPI XL140 array processor where the final beamforming is accomplished and the data is separated into range cells (400m resolution over 400km yields 1000 range cells times the number of channels) and stored in a VAX 8250. These cells continue to be "stacked" in memory throughout the integration period which is determined by the required processing bandwidth. This may range from pseudo-real time processing to integration times of around thirty minutes. After sufficient data

has been collected an fft is performed across each "stack" of cells. This yields the Bragg response of the sea echo and the return from any target that may be in a given cell. By measuring the change in phase of this return the targets radial velocity is determined. This final data is stored on a database and can be displayed on a graphics work station used to emulate an enhanced PPI (Plan Position Indicator) type display.

Conclusion

The NRSL radar at Cape Race represents a significant increase in the ability to monitor conditions on Canada's east coast as well as requiring state-of-the-art in certain hardware areas to be nudged. The prototype is presently operating in a very rudimentary fashion and routinely measures sea state out to 400km. Full operation is scheduled for June 1990.

References

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